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Communications network using priority classes

Abstract:

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(54) Communications network using priority classes

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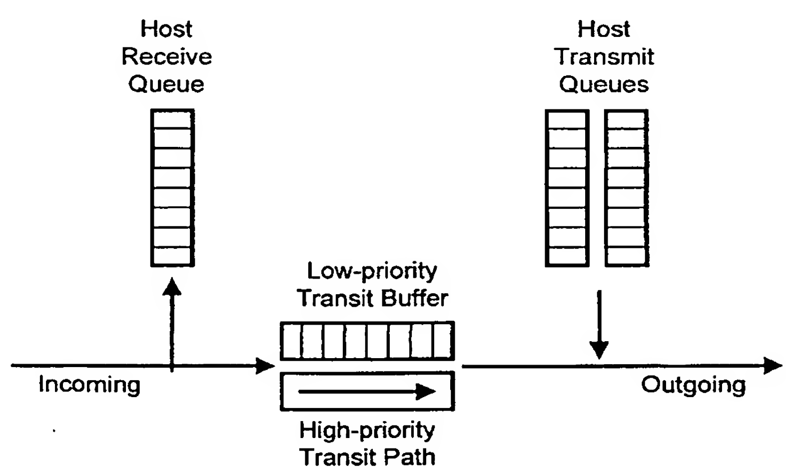

Figure 3

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Description

[0001] The present invention relates to a communications network, and in particular to a packet network and to nodes for use in such a network.

[0002] In some currently proposed architectures for optical networks carrying packet traffic, packets are assigned different priorities in order, for example, to support different quality of service (QoS) levels. Packets originating at a node may be assigned to one of a number of different transmit queues, depending on their relative priority. In some previously proposed "drop and insert" node architectures, when a packet arrives at a destination node, it is removed from the network, and the resulting vacancy may be immediately filled by an outgoing packet from a transmit queue. Such an arrangement is disclosed, for example, in the paper by J. R.Sauer et al "A Soliton Ring Network" Journal of Lightweight Technology, Vol. 11, No. 12, December 1993, Pages 2182-2190.

[0003] According to a first aspect of the present invention, there is provided a method of operating a node in a communications network, the method comprising:

(a) receiving a transit packet at the node,
(b) determining a priority assigned to the transit packet,
(c) when the transit packet is determined to have a relatively lower priority, then removing the said transit packet, and in that case,
(d) outputting from the node in the vacancy created by removing the said packet another packet determined to have a relatively higher priority.

[0004] By a "transit packet" is meant a packet handled by a node that does not originate from the node, and is not addressed to the node.

[0005] The present invention significantly enhances the effectiveness of packet prioritisation schemes in a communications network, by selectively removing lower priority transit packets and replacing them with higher priority packets. The invention is applicable both to slotted networks, and to networks with e.g. variable length packets received asynchronously at the node.

[0006] Preferably the node includes a continuous-flow transmission path connecting the input to the node to the output from the node and an alternative path connecting the input to the node to the output from the node and including one or more packet queues, and the method includes outputting a transit packet determined to have a relatively higher priority via the continuous-flow transmission path.

[0007] A continuous-flow transmission path is one which transmits packets in a steady, continuous fashion without using queues or other variable delays. The continuous-flow-transmission path may be entirely in the optical domain. Alternatively, part or all of the continuous-flow transmission path may be in the electrical domain. In this case, electrical-optical conversion may be carried out at the input and output of the node.

[0008] According to another aspect of the present invention, there is provided a communications system comprising a communications network having a ring topology and comprising at least two duplicate transmission paths, and

a plurality of nodes connected to the ring network each node being arranged to output onto the ring network packets addressed to one or more other nodes on the network, and
switch means bridging the at least two transmission paths, and arranged, in the event of a failure in one of the transmission paths, to divert packets from the said one of the transmission paths onto the other of the transmission paths,
characterised in that each node is assigned a different network address for each of the transmission paths, and in that one or more of the nodes is arranged to remove a packet from the network when the packet carries the node address corresponding to the transmission path on which the packet was received.

[0009] One advantage of the dual ring packet network is that it offers enhanced resilience. In the event of a failure in one of the rings, "ring wrap" is used to divert packets onto the other of the rings. The present inventor has recognised that it is important that, in the event of ring wrap, that the destination node still recognises packets addressed to it and handles packets in the normal way, but that at the same time it is necessary that control processors at the nodes should be aware that ring wrap has occurred. This aspect of the invention makes this possible, while imposing minimal signalling or processing overheads. Suppose a node has the address A on the outer ring and address B on the inner ring. The node will eject any packet that it finds on the outer ring with ADDRESSEE=A and will eject any packet that it finds on the inner ring with ADDRESSEE=B. A packet with ADDRESSEE=A that is wrapped onto the inner ring will be ejected by the node. Similarly a packet with ADDRESSEE=B that is wrapped onto the outer ring will be ejected by the node. In preferred example this ensures that a multicast packet transmitted from the node in question on the outer ring and created with ADDRESSEE=A will not be prematurely ejected if it is wrapped back onto the inner ring before reaching all the other nodes. Another example is an express control packet used for a TTL (time-to-live) mechanism, where this ensures the packet is not prematurely ejected if there is a ring wrap.

[0010] Systems embodying the present invention will now be described in further detail, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a schematic showing a prior art network;
Figure 2 is a schematic showing a first example of a network embodying the present invention;
Figure 3 shows the data flows through a node in the network of Figure 2;
Figure 4 is a schematic showing the architecture of a prior art node;
Figure 5 is a schematic showing the architecture of a node embodying the present invention;
Figure 6 is a schematic showing alternative node architecture;
Figures 7i to 7iv show alternative configurations for the node of Figure 5;
Figure 8 illustrates the substitution of a high priority packet for a low priority packet;
Figure 9 shows packet queues within a node for different packet types;
Figure 10 shows the format of an optical packet;
Figure 11 shows the use of dual addresses;
Figure 12 shows a ring-wrap operation;
Figure 13 shows contention at a node output; and
Figure 14 shows logic and synchronisation circuits.

[0011] Figure 1 shows a prior art architecture developed by Cisco and known as the DPT (Dynamic Packet Transport) ring architecture. In this scheme, Internet routers are placed on two concentric counter-directional rings. The rings consist of a sequence of optical fibre links, each of which terminates at the input and output ports of the routers. One of the rings is known as the inner ring and the other as the outer ring. Data packets are sent in one direction and corresponding control packets are sent in the opposite direction on the other fibre. This IP (Internet Protocol) ring network is designed to provide a number of features. In particular, it supports statistical multiplexing of packets with no provision of point-to-point connections or use of dedicated bandwidth for interconnection of routers or for protection. It is also designed to support packet prioritisation and to offer multiple levels of queuing and scheduling and to support both unicast and multicast transmissions. In the network of Figure 1, by contrast with the network described below with reference to Figure 2, the signal transmission path is interrupted at each node.

[0012] Figure 2 shows a network embodying the present invention. A communications network 1 comprises concentric outer and inner rings 2.1, 2.2. The rings carry optical packets. A number of nodes 3a to 3g are connected to the rings. In this example, each of the nodes 3a to 3g is an Internet Protocol router. In operation, one of the routers, for example 3a, outputs an optical packet addressed to another of the routers, for example 3d, onto one of the dual concentric rings. The optical packet output by node 3a carries the network address of node 3d in an address field in the packet header. The packet passes around the ring. At each intermediate node, the packet address is compared with the address of the respective node. If the packet is not addressed to a given intermediate node, then the packet passes on to the next node, and so on. At the destination node, the address is read and the packet is recognised as being intended for receipt at that node. The packet, in the case of a unicast transmission is removed from the network at that node. It may then, for example, be converted to the electrical domain for onwards transmission to a customer terminal on an electronic network connected to the respective node.

[0013] Figure 3 shows the flow of received and transmitted data packets at one of the nodes on one of the fibre rings. An incoming data packet is (i) sent to host receive queue (if it has reached its destination) or (ii) is passed over for onward transmission. A multicast packet may both be sent to the host receive queue and also be forwarded for onward transmission. Packets for onward transmission are treated according to their priority: a low-priority packet is passed to a transmit queue. An express high-priority, packet is passed immediately to the outgoing path without queuing. When capacity on the ring allows, a packet from one of the transmit queues may be passed to the outgoing path. Multiple transmit queues may be used to manage prioritisation of outgoing traffic from the node.

[0014] In this example, the optical fibre rings and the nodes are configured to provide a continuous optical path for express packets.

[0015] In a continuous transmission path signals stream into and out from the path at a continuous and uniform rate. The path may be a continuous optical transmission path. The continuous optical transmission path may contain a substantially fixed delay as in Figure 3. In the case of a continuous transmission path in the electrical domain the path may contain storage elements such as an FIFO (first-in first-out) buffer. This differs from conventional systems, however, in that, in normal operation, the output from the buffer is continuous and regular, so that the input and output of the buffer occur at substantially the same rate. In conventional prior systems, a buffer is used to hold transit packets in a queue which is serviced at rates and/or times which are dependent on factors such as packet priorities, queue length, status of contending queues etc.

[0016] A further function carried out by the control circuits is to determine whether the time-to-live (TTL) of a packet has expired. If the time-to-live is determined to have expired, then again a control signal is sent to the switch to cause such a packet to be ejected from the onwards transmission path. When one of the nodes generates and outputs an optical packet onto the ring, a value is written in a phase field "PH" in the packet header. One of the nodes functions as a master node. The master node outputs multicast express control packets that travel around each ring to inform each node of the current phase value. The phase value is regularly updated, at a rate of at least once per round-trip time for speed-of-light travel around the ring. The updating of the phase value is carried out by the master node incre-

menting the value, for example, in the case of one control packet per round trip of the ring, the phase value is incremented by 1 (modulo 3). Each ring periodically receives and stores the current phase value as indicated by one of the multicast express control packets from the master node. When any other express packet is received at the node the control logic in the node determines whether the value in the PH field of the received express packet differs from the current phase value by an amount sufficient to indicate that the packet is expired. For example, in the case of one control packet per round trip, the node determines whether the value in the PH field of the received packet is such that:

(current_phase - PH) mod 3> 1

[0017] If this inequality is satisfied, then the packet is expired and should be purged from the ring. This may be the case, for example, because the packet is addressed to a node which is currently malfunctioning or because there is an error in the address of the packet.

[0018] Figure 4 shows the traditional 'drop-and-insert' (D&I) architecture that has been widely considered previously for optical packet networks (e.g. J R Sauer, M N Islam and S P Dijaili, "A soliton ring network", Journal of Lightwave Technology, vol. 11, no. 12, December 1993, pp. 2182-2190). The node contains a 2x2 optical crossbar switch. When the switch is in the bar (straight-through) position: (i) an optical packet on the incoming fibre is 'dropped' (i.e. switched to the node receiver); or (ii) an optical packet created by the host transmitter is 'inserted' (i.e. switched to the outgoing fibre); or both (i) and (ii) occur simultaneously. A limitation of the D&I node architecture is that when a packet is received by the node it is physically removed from the optical path between the incoming and outgoing fibres. The only method for multicasting a packet is, at each node, to drop the packet and then subsequently reinsert it when sufficient vacant capacity on the ring becomes available. Therefore this architecture cannot support multicasting of express (high-priority) transit packets.

[0019] Figure 5 shows a preferred form of the new node architecture that we have invented. Instead of 'drop-and-insert' (D&I), this new architecture provides the function of 'copy-eject-and-insert' (CEI). In the case of a D&I node, packets are extracted from the transmission path for the purpose of receiving them at a node. In the case of a CEI node, packets are copied but not extracted from the transmission path for the purpose of receiving them at a node. All incoming traffic is copied to the node, for example by means of a passive optical coupler as shown in Figure 5. In use, an incoming fibre from one of the optical rings passes to a coupler 5.1. From the coupler 5.1, one optical path passes through a further length of fibre 5.3 providing a fixed delay to an optical crossbar switch 5.4. An outgoing fibre connected in the fibre ring passes from one of the output ports of the crossbar switch. The other output from the coupler 5.1 is split again, for example, using a further coupler 5.2. One branch of the output from this further coupler is used to provide a copy of the optical packet on the incoming fibre. This copy may be passed, for example, to the host receive queue. The other branch of the output of the further coupler passes to control circuits. These control circuits may, for example, read a header carried with the optical packet, and carry out associated logic operations. A control output is generated by the control circuits and passes to the crossbar switch. If the control circuits determine that the packet is addressed to the respective node, then the crossbar switch is set to the cross state in order to eject the packet (in the case of a unicast transmission). If an incoming packet has reached its destination or is otherwise intended to terminate at the node, the packet is also ejected from the ring, for example by means of the crossbar switch as shown in Figure 5. Simultaneously, or whenever sufficient vacant capacity on the ring become available, a packet may be inserted onto the ring by the node. The control logic and synchronisation sub-systems use information contained in the packet (for example in the packet header) and other information (for example the filling status of transmit queues and the status of control flags) to operate the crossbar switch. Figure 5 shows a fixed optical delay, which allows sufficient time for the operation of these control logic, synchronisation sub-systems and switch before the arrival of the packet at the switch. As in the D&I architecture, an express (high priority) transit packet is passed directly to the outgoing fibre. However, unlike D&I, the CEI architecture allows express transit packets to be multicast, because they are simultaneously copied without delaying their onward passage.

[0020] Figure 14 shows the control logic subsystem in more detail. It includes optical logic stages 141 and combinatorial electronic logic gates 142. The four optical blocks (synch, address recognition PH reader and Unicast/Multicast) each have copies of the optical packet to the input. The output from the synchronisation block is an optical path to each of the other three optical blocks. The synch block may be based on one of the self-synchronisation techniques we have described in our patent EP-B-687370 (eg. using pulses separated by 1.5 bit periods input to an optical AND gate). The address recognition block may be based on the technique we have described before in that patent. Addresses are coded using specially selected binary words, and recognised by inputting address and target word to an optical AND gate. The output from the AND gate is converted to give an output from the block that is an electrical binary signal that says packet ADDRESSEE matches/does not match local address. The PH may be two optical AND gates, each having the optical packet as one input and a synch pulse as the other input - this synch pulse timed to overlap with one of the PH bits. The output from PH reader block is two parallel electrical binary signals - each denoting one of the PH bits. The UNI/MULTI reader may be one optical AND gate, having the optical packet as one input and a synch pulse as the

other input - this synch pulse timed to overlap with the UM bit. The output from UNI/MULTI reader block is one electrical binary signal - denoting unicast/multicast. These electrical signals, together with signals from the queue status then pass to the high-speed electronic logic part. This part performs the logic which is set out in - the table below describing the action of the node for various types of packet (e.g. multicast low-priority transit packet, etc). The output from this electronic logic is a binary electrical signal to set the 2x2 cross bar optical switch configuration.

[0021] Each stage of this logic has to operate within a time shorter than the shortest packet, e.g. for a 50 byte packet at 100 Gbit/s = 4 ns. Since the optical stage and electronic logic stage are arranged in pipeline, each stage would have to take less than the minimum time (eg 4 ns). The optical stage is ultrafast - e.g. using four-wave mixing in semiconductor optical amplifier, or TOAD device, etc. to implement the optical AND gate. Since the electronic logic required is simple it is possible to construct suitable fast circuit using hard-wired combinatorial logic.

[0022] Figure 6 shows an example of the CEI architecture in an alternative form. Here there are two crossbar switches, SW1 and SW2. (For clarity, the control logic and synchronisation sub-systems are not shown.) In this case not all incoming packets are copied; instead only those that arrive whilst SW1 is in the cross state will be copied. In this case an express multicast packet may be copied and immediately reinserted onto the ring if switches SW1 and SW2 are both placed in the cross state. However in this case the express multicast packet is delayed by the transit time of the feedback loop from SW1 to SW2 and back again to SW1. The alternative form of the CEI architecture shown in Figure 6 has certain drawbacks: First, the forced additional delay for express multicast packets increases the probability of contention at SW1 (described further below) unless special preventative measures are used (such as, for example, providing a sufficient time guard band following an express multicast packet, with the resulting penalty of reduced network throughput and higher complexity). Second, the architecture shown in Figure 6 requires two optical switches, rather than one.

[0023] In the case of the D&I architecture (Figure 4), the extraction of packets from the transmission path for the purpose of receiving them at a node is necessarily a selective process in the optical domain, and may be performed for example by an optical crossbar switch. In the preferred form of the CEI architecture (Figure 5), the copying of packets from the transmission path for the purpose of receiving them at a node is non-selective in the optical domain, and may be performed for example by a passive optical coupler.

[0024] In the CEI architecture the continuous transmission path for express transit packets is preferably a continuous optical transmission path, but not necessarily so, as shown in Figures 7 (i)-(iv). Figure 7(i) shows a preferred arrangement with a continuous optical transmission path for express transit packets. Figure 7(ii) shows a transponder (a regenerator using optical-electrical and electrical-optical conversion stages). Figure 7 (iii) shows a case where the copy function is performed in the electrical domain. Figure 7(iv) shows a case where the copy, eject and insert functions are all performed in the electrical domain. In this case the switch can be a 1x2 electrical switch, and as in the case of optical switching, the channel left open circuit is in effect 'ejected'.

[0025] Figure 7(iv) is distinguished from conventional nodes by a 'continuous transmission path'. In the continuous transmission path signals stream into and out from the path at a continuous and uniform rate.

[0026] An important feature of an optical packet network with different priority classes is the ability to reallocate the time occupied on the ring by a transit packet to another packet with higher priority. The reuse of certain time slots using a D&I optical node architecture is previously known. For example, the previously cited paper of Sauer et al describes a D&I optical node in which a slot made vacant by dropping a packet (i.e. removing from the optical ring a packet when the packet destination address matches the node address) can be immediately reused by inserting a transmit packet. Here, distinctively, we reallocate any time-position by ejecting an incoming packet from the ring so as to vacate the time position, and immediately or simultaneously insert into the same time position another packet taken from one of the transit or transmit queues. Using the CEI architecture, the steps required to reallocate to a packet of higher priority a time slot currently occupied by an incoming transit packet are: copy the incoming transit packet; determine its priority; if appropriate for reallocation, then do {eject the packet from the ring; deliver the packet copy to the transit buffer; transmit another packet of higher priority reusing the same time position}. This is illustrated in Figure 8. Notice that the CEI architecture is not essential for this process. For example, using a D&I architecture the steps required would be: determine the priority of an incoming transit packet; if appropriate for reallocation, then do {drop the packet; store the packet for later transmission; and transmit another packet of higher priority reusing the same time position}.

[0027] Figure 9 shows the flow of incoming and outgoing packets in the optical CEI node of Figure 5, so as to realise the architecture of Figure 3. All packets are assumed to be in one of two priority classes: low and high (express). Packets may also be unicast or multicast, and they may be data packets (with a payload of user data) or control packets (uniquely for network control purposes). All incoming packets are copied, whereupon they may be allocated to various input queues or else discarded. The operations at the node to handle different types of legitimate (e.g. non-expired) incoming packet are as follows:

- Unicast
    - Express transit packet: The crossbar switch is put in the bar (straight through) state so that the packet is passed directly to the outgoing fibre. The packet copy is discarded.
    - Express packet addressed to node: The crossbar switch is put in the cross state to eject the packet from the ring. The packet copy is delivered to the input queue, and subsequently sorted according to whether it is a data or control packet.
    - Low-priority transit packet: The crossbar switch is put in the cross state to eject the packet from the ring. The packet copy is delivered to the low-priority transit buffer.
    - Low-priority packet addressed to node: The crossbar switch is put in the cross state to eject the packet from the ring. The packet copy is delivered to the input queue, and is subsequently sorted according to whether it is a data or control packet.

- Multicast
    - Express packet (different source): The crossbar switch is put in the bar state so that the packet is passed directly to the outgoing fibre. The packet copy is delivered to the input queue, and is subsequently sorted according to whether it is a data or control packet intended for delivery to the node, otherwise it is discarded.
    - Express packet (node is the source): The crossbar switch is put in the cross state to eject the packet from the ring. The packet copy is discarded.
    - Low-priority packet (different source): The crossbar switch is put in the cross state to eject the packet from the ring. The packet copy is delivered to low-priority transit buffer. The packet copy is also delivered to the input queue, where it is subsequently sorted according to whether it is a data or control packet intended for delivery to the node, otherwise it is discarded.
    - Low-priority packet (node is the source): The crossbar switch is put in the cross state to eject the packet from the ring. The packet copy is discarded.

[0028] Packets for transmission from the node are selected from the low-priority transit buffer or the transmit queues according to the current status of queue depths, appropriate rate controls, fairness algorithm, etc. Subject to these controls, packets are transmitted as vacant capacity becomes available on the ring (either vacant capacity on the incoming fibre or new vacant capacity created by the ejection of packets from the ring by the node itself).

[0029] Each packet carries an appropriate MAC protocol header, designed according to the principles set out earlier (Figure 10 shows a suggested example). This MAC header can consist of two parts: one part (which we call the 'optical MAC header') contains the minimum information needed for the processing functions that must be carried out at high speed 'on the fly' to enable the operations listed above. The second part of the MAC header contains information needed for other Layer 2 functions.

[0030] In the example shown in Figure 10, SS (self-synchronisation) is a 2-bit field used for timing recovery. ADDRESSEE is a 10-bit field used to indicate which node should strip the packet from the ring. In the 'Spatial Reuse Protocol' (SRP) described by Cisco (part of the Dynamic Packet Transport), packets are stripped from the ring by the destination node in the case of unicast packets. It is proposed here that for the purpose of routing in the high-speed network, the optical MAC header will not include both the source and destination addresses, but instead will contain a single address field ADDRESSEE. For the transmission of a unicast packet, ADDRESSEE will be set to the destination address. For the transmission of a multicast packet, ADDRESSEE will be set to the source address. A node is required to eject a packet from the ring if ADDRESSEE matches the address of the node. UM (unicast/multicast) is a 1-bit field used to indicate whether the packet is unicast or multicast. PH (phase) is a 2-bit field with a dual purpose; as described more fully below, PH indicates the priority of the packet and also contains a simple time-to-live mechanism. P (parity) is a 1-bit field used to set the parity of the optical MAC header (approximately 2 bytes), and will be used in combination with 'on the fly' parity checking to provide some header integrity.

[0031] The reading of the optical MAC header must be performed 'on the fly' using very simple high-speed logic operations. For ultra-high-speed optical implementation, processing based on simple optical logic gates, such as AND, will be used. Various methods of timing recovery based on self-synchronisation are described in our patent EP-B-687370. For example, the field SS could consist of 2 return-to-zero format optical pulses separated by 1.5 bit periods, and self-synchronisation would be based on the output from an optical AND gate whose first input is a copy of the packet and the second input is a further copy of the packet delayed by 1.5 bit periods with respect to the first. The output from the AND gate is an optical pulse in precise synchronism with the start of the packet. This pulse (which we term here the 'timing pulse') can then be used for a variety of operations on the fly. The timing pulse may be used in the process of determining whether there is a match between ADDRESSEE and the address of the node, as described in our patent EP-B-687370. The timing pulse may also be used in combination with optical AND gates to read the fields UM and PH.

[0032] The dual ring structure is resilient because, in

the event of an isolated fibre break or node failure, the nodes can perform the 'ring wrap' operation illustrated in Figure 12 [as described for example in Cisco's recently published white paper on Dynamic Packet Transport Technology and Applications]. For proper operation of the control mechanisms which allow the network to reconfigure and re-establish after ring wrap, it is clearly necessary for the nodes to distinguish between those incoming packets which are travelling on their 'correct' ring and those that have been wrapped onto their 'wrong' ring. Here we propose the technique of 'dual addressing' to avoid the need for an additional header field to indicate the 'correct' ring for each packet. Dual addressing is illustrated in Figure 11. Rather than provide each node with a single address, it is proposed to provide each node with two addresses, one for each of the rings. In this case, the transmitter of a packet uses the appropriate value of ADDRESSEE corresponding to the ring that is being used. In the event of ring wrap, the usual rule for packet stripping is simply followed (a node is required to eject a packet from the ring if ADDRESSEE matches the address of the node), without the need to read further header fields to check whether the packet has been wrapped onto the 'wrong' ring.

[0033] Some network control operations require point-to-point signalling between adjacent nodes. This can be done in a number of ways: creation of an independent control packet; 'piggy-back' technique such as overwriting certain fields in a newly created data packet or in a low-priority transit packet; or out-of-band signalling. Out-of-band signalling could be performed in time guard bands between packets.

[0034] A potential limitation of the CEI node architecture is the possibility of contention at the eject-and-insert switch. This is illustrated in Figure 13. Contention may arise when an incoming packet B arrives when the switch is in the cross position and the node is in the process of inserting a packet A. In the absence of an optical buffering mechanism, various possibilities for contention resolution are available including switch over to the bar state to allow B to pass, thus forcing the ejection of part of A. Resend A later. The recipients of A will recognise that the packet has been truncated, and discard it.

Claims

1. A method of operating a node in a communications network, the method comprising:

    (a) receiving a transit packet at the node,
    (b) determining a priority assigned to the transit packet,
    (c) when the transit packet is determined to have a relatively lower priority, then removing the said transit packet, and in that case,
    (d) outputting from the node in the vacancy created by removing the said packet another packet determined to have a relatively higher priority.

2. A method according to claim 1 in which the node includes a continuous-flow transmission path connecting the input to the nodes to the output from the node, and the method includes outputting a transit packet determined to have a relatively higher priority via the continuous-flow transmission path.

3. A method according to claims 1 or 2, in which the packet is received at the node in the optical domain.

4. A method according to claim 3, when dependent on claim 2, in which the continuous-flow transmission path is an optical transmission path.

5. A method according to any one of the preceding claims, including placing a transit packet determined to have a relatively lower priority in a queue at the node, and subsequently outputting the said transit packet from the queue onto the network in a time position later than the position originally occupied by the said transit packet.

6. A method according to any one of the preceding claims, in which the transit packets are variable length packets.

7. A method according to any preceding claim, in which the said node and the other nodes operate synchronously at the packet-level and asynchronously at the bit-level.

8. A node for connection in a communications network, the node comprising:

    (a) an input arranged to receive packets from the network,
    (b) an output arranged to output packets onto the network,
    (c) switching means arranged selectively to remove packets from the network, and to insert the packets into the network, and
    (d) control means arranged to determine a priority assigned to a transit packet arriving at the node, and arranged to control the switch means to remove a transit packet determined to have a relatively lower priority, and to insert in the vacancy created by removing said packet another packet determined to have a relatively higher priority.

9. A communications network including one or more nodes according to claim 8.

10. A communications network according to claim 9, in which the network is an optical communications

network.

11. A communications network according to claims 9 or 10, in which the communications network includes a cyclical continuous-flow transmission path.

12. A communications system comprising a communications network having a ring topology and comprising at least two duplicate transmission paths, and

    a plurality of nodes connected to the ring network each node being arranged to output onto the ring network packets addressed to one or more other nodes on the network, and
    switch means bridging the at least two transmission paths, and arranged, in the event of a failure in one of the transmission paths, to divert packets from the said one of the transmission paths onto the other of the transmission paths,

    characterised in that each node is assigned a different network address for each of the transmission paths, and in that one or more of the nodes is arranged to remove a packet from the network when the packet carries the node address corresponding to the transmission path on which the packet was received.

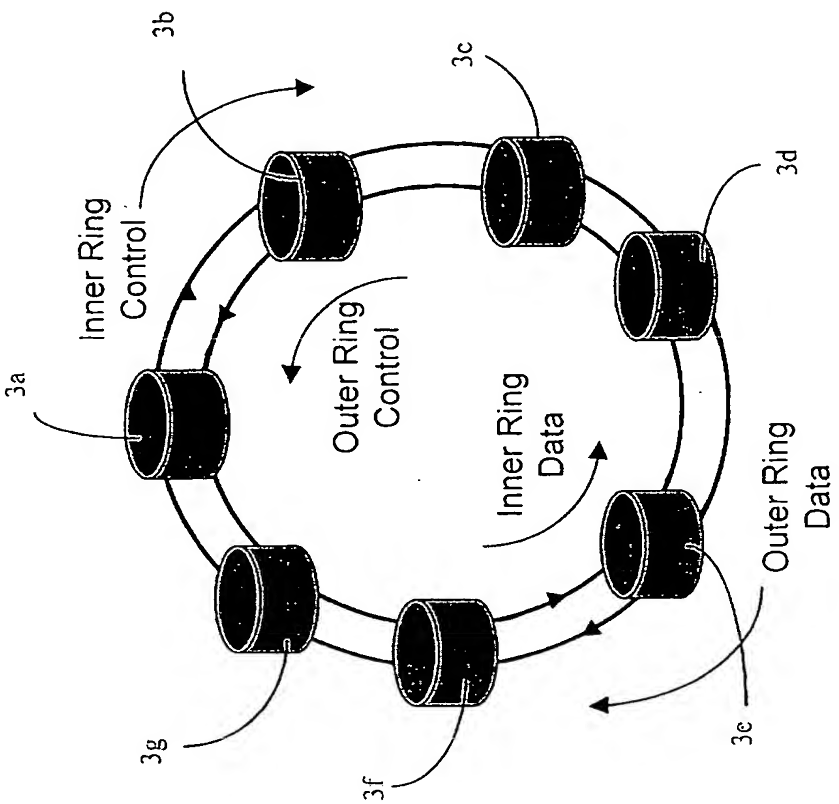

3a
3b
3c
3d
3c
3f
3g
Inner Ring Control
Outer Ring Control
Inner Ring Data
Outer Ring Data

Figure 1

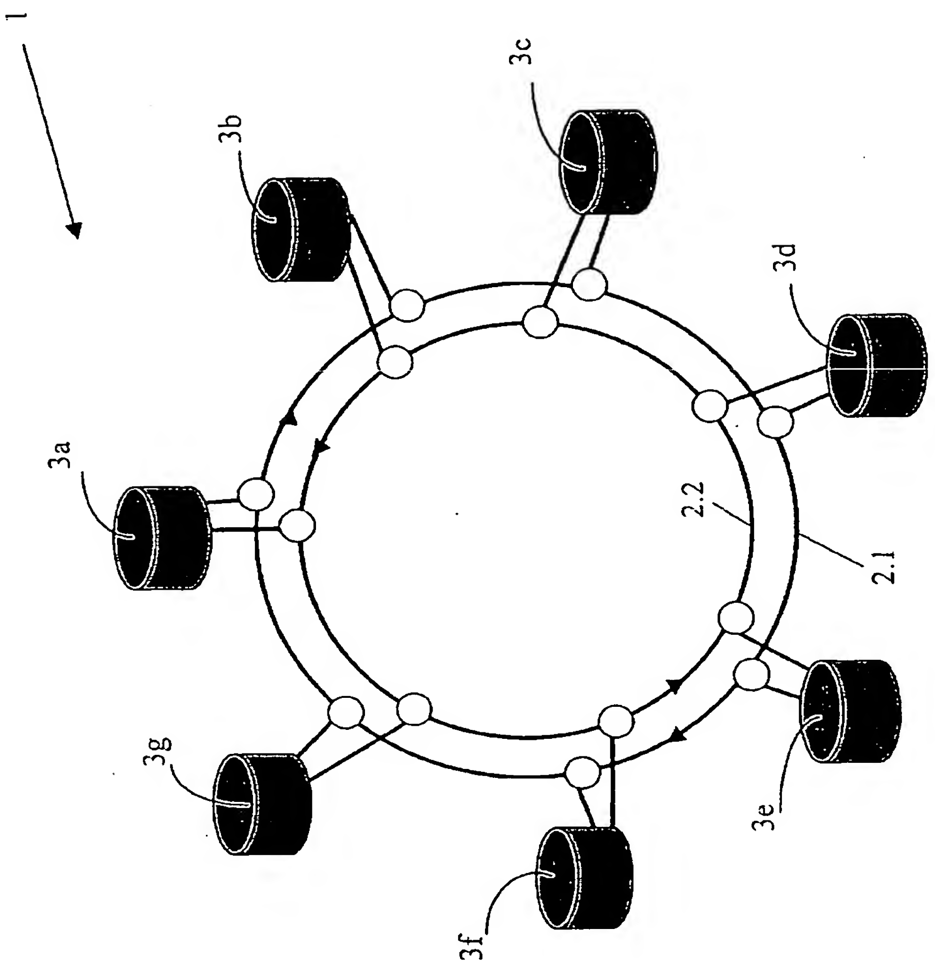


Figure 2

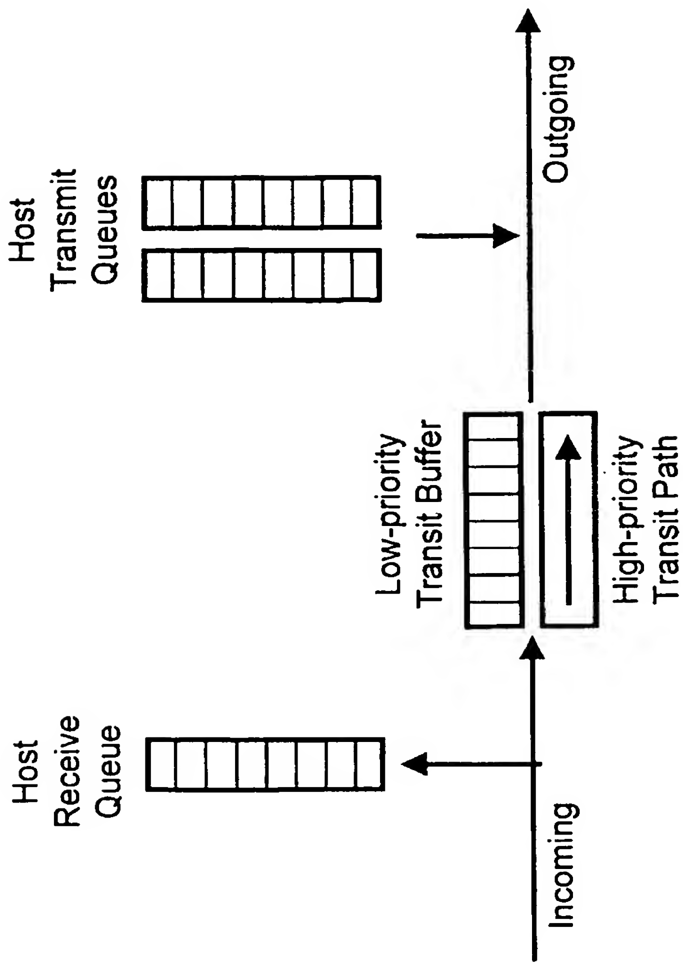

Host
Transmit
Queues
Outgoing
Low-priority
Transit Buffer
High-priority
Transit Path
Host
Receive
Queue
Incoming

Figure 3

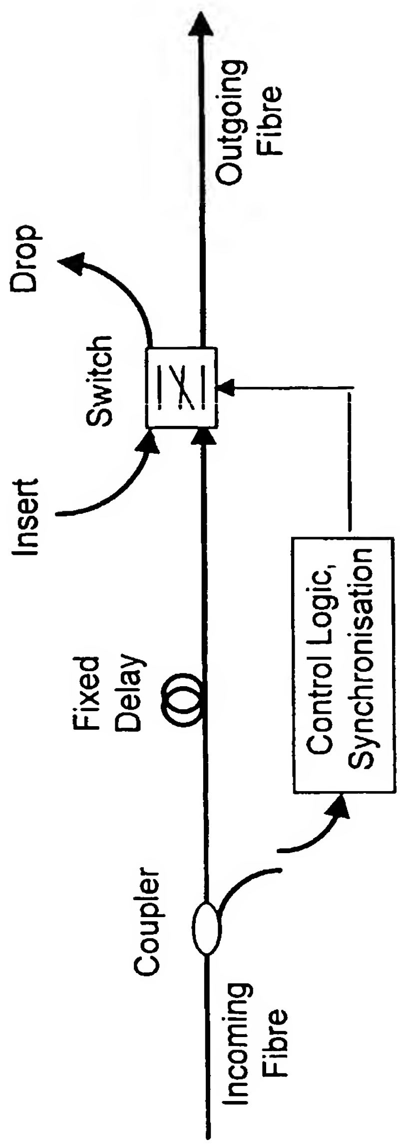

Drop
Outgoing Fibre
Switch
Insert
Fixed Delay
Control Logic, Synchronisation
Coupler
Incoming Fibre

Figure 4

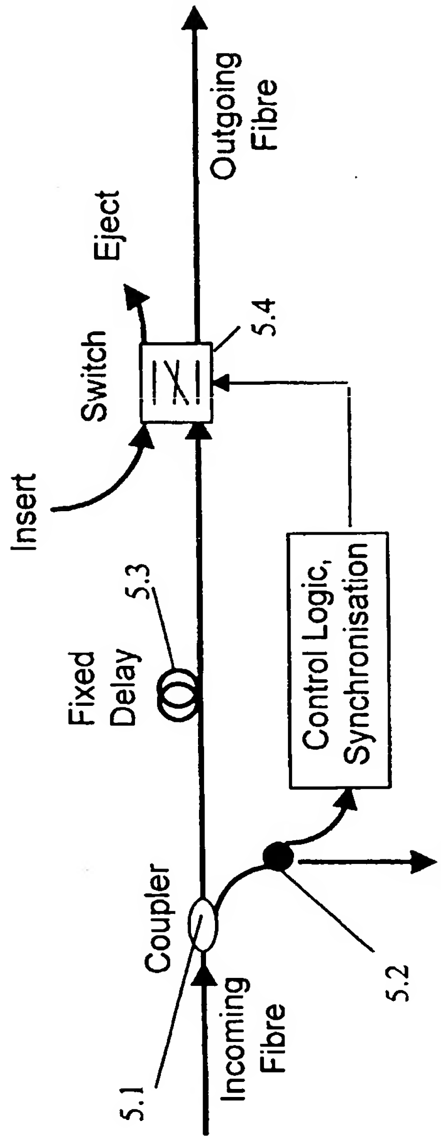

Outgoing Fibre
Eject
Switch
5.4
Insert
Fixed Delay
5.3
Control Logic, Synchronisation
Coupler
Copy
5.1
Incoming Fibre
5.2

Figure 5

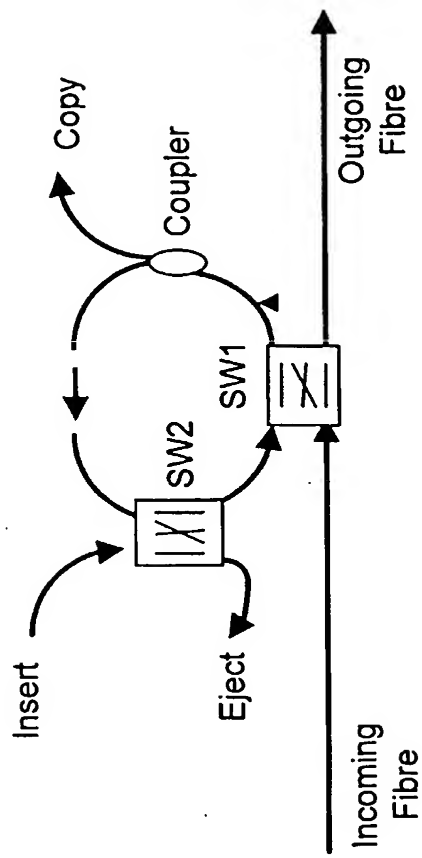

Copy
Coupler
Outgoing Fibre
SW1
SW2
Insert
Eject
Incoming Fibre

Figure 6

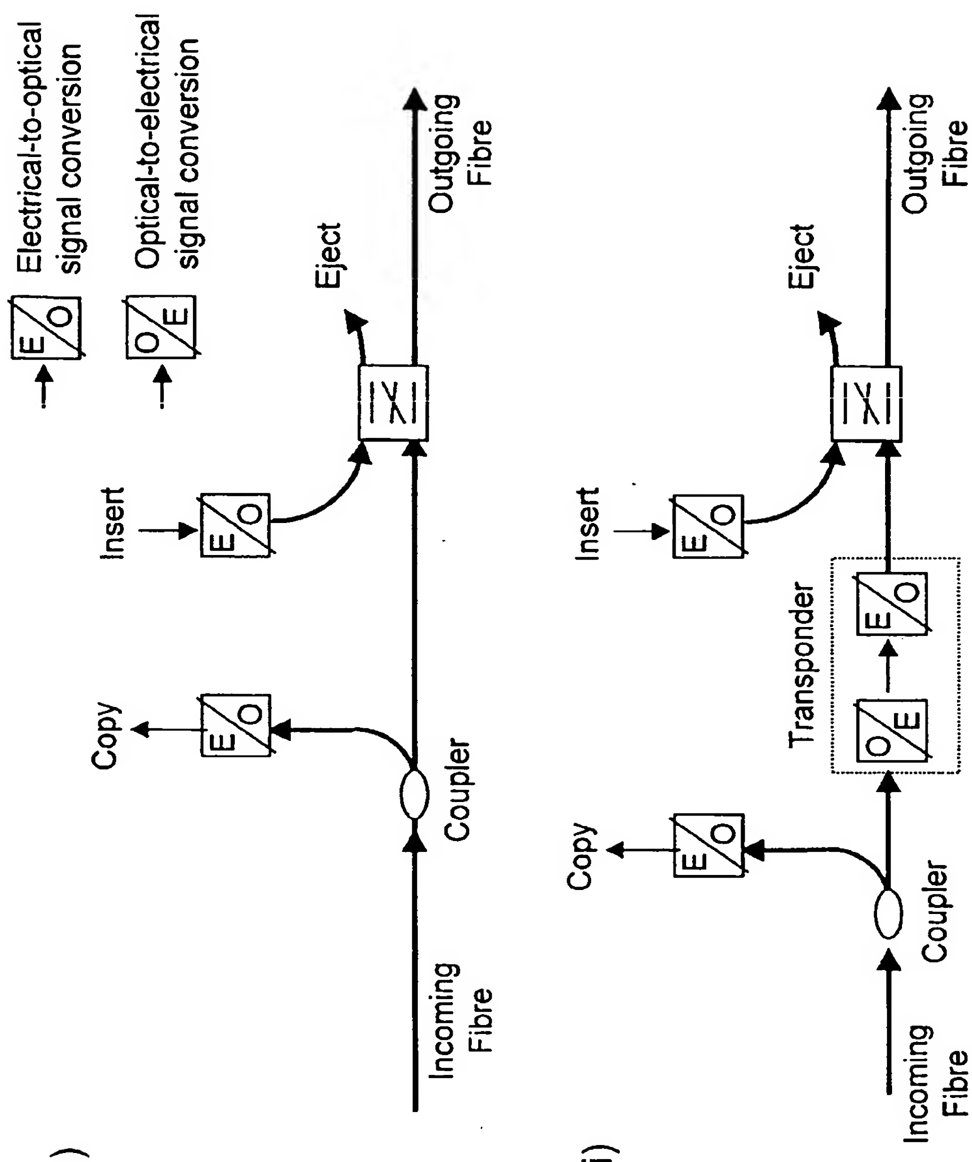


Figure 7(i), 7(ii)

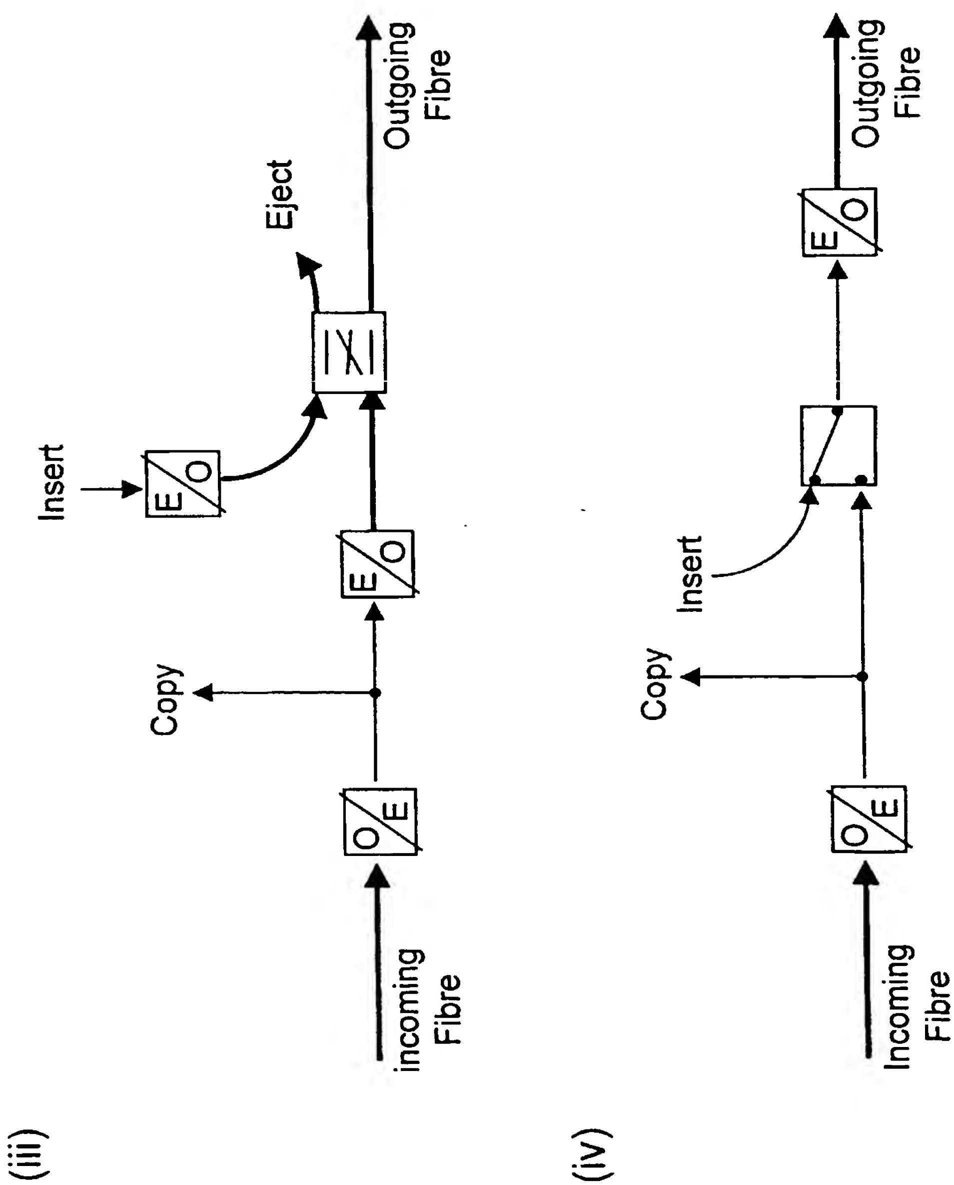
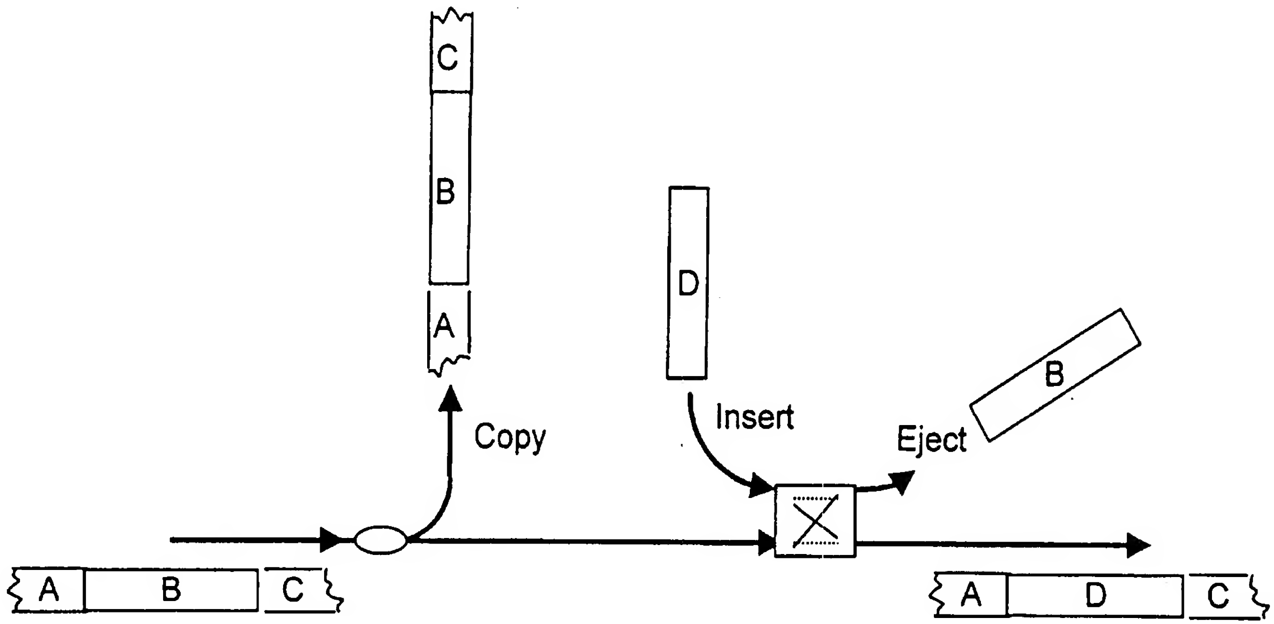


Figure 7(iii), 7(iv)



B = received packet or lo-priority transit packet

D = packet from transmit queue or lo-priority transit buffer

Figure 8

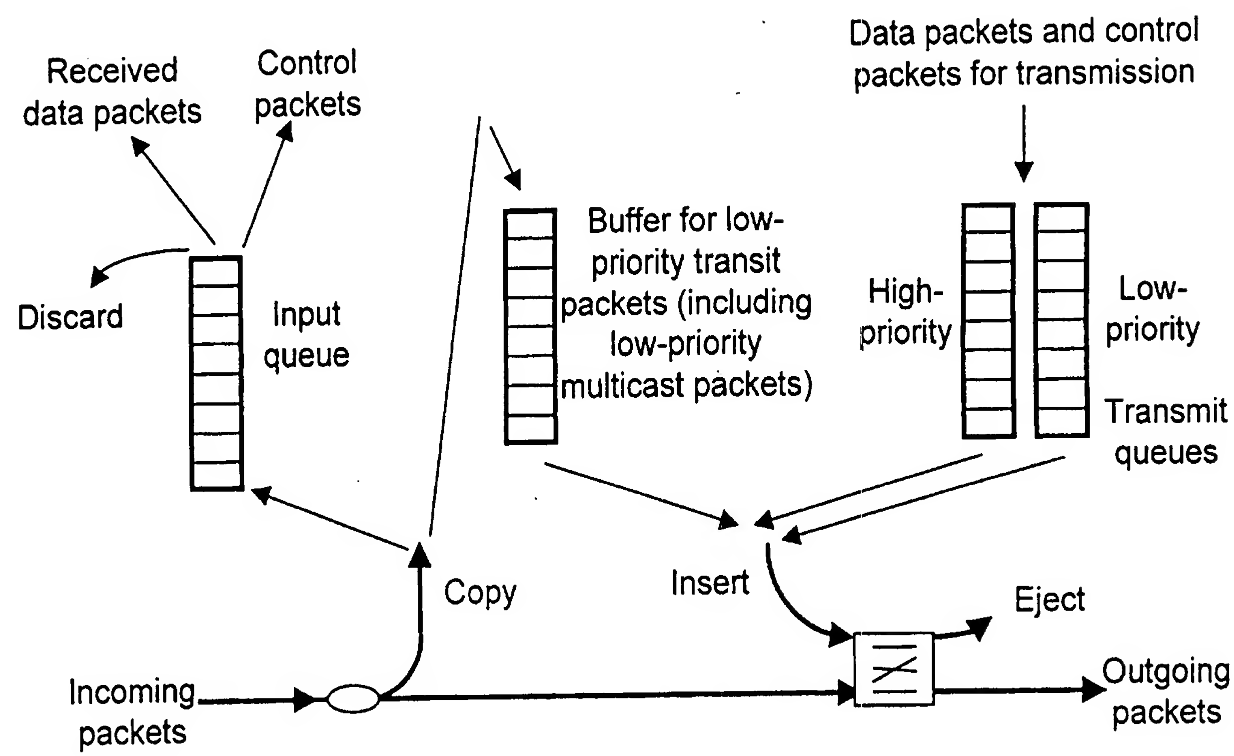

Received
data packets
Control
packets
Discard
Input
queue
Buffer for low-
priority transit
packets (including
low-priority
multicast packets)
Data packets and control
packets for transmission
High-
priority
Low-
priority
Transmit
queues
Copy
Insert
Eject
Incoming
packets
Outgoing
packets

Figure 9

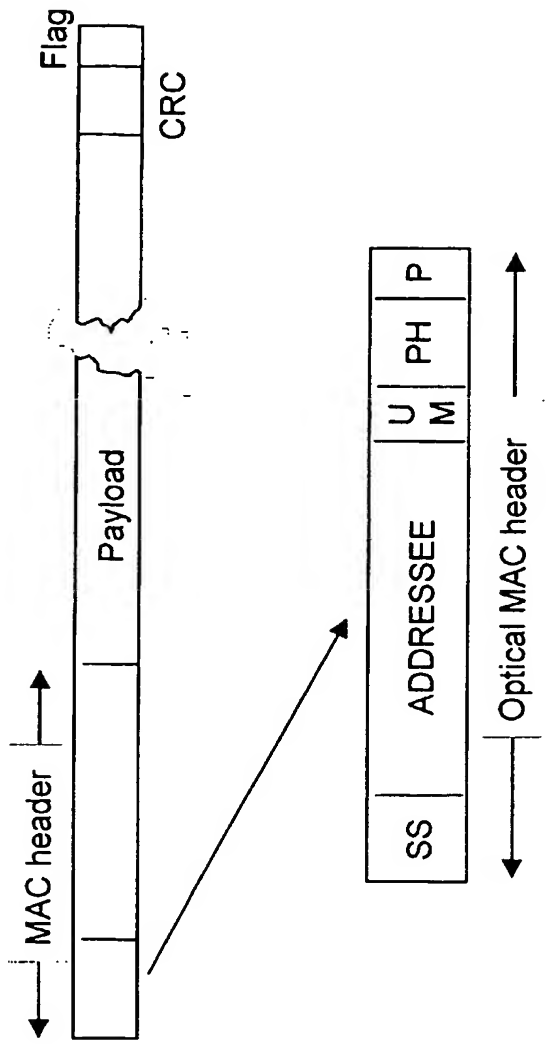

Flag
CRC
Payload
MAC header
SS
ADDRESSEE
U M
PH
P
Optical MAC header

Figure 10

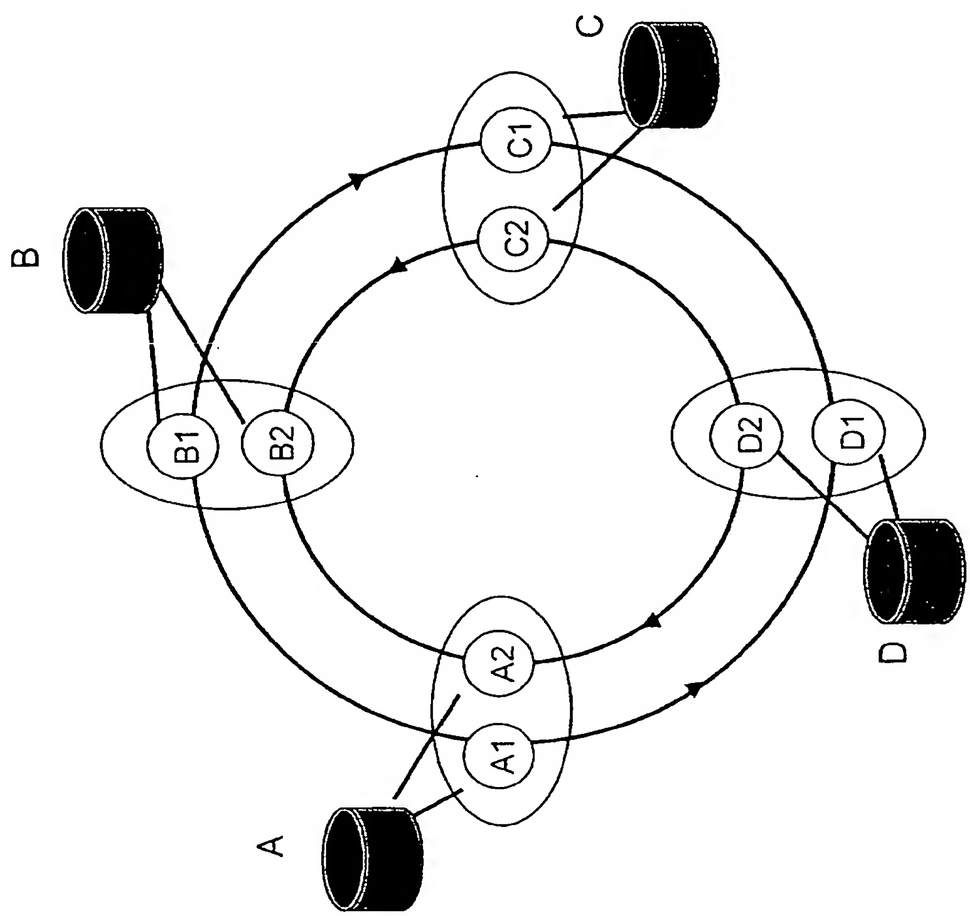


Figure 11

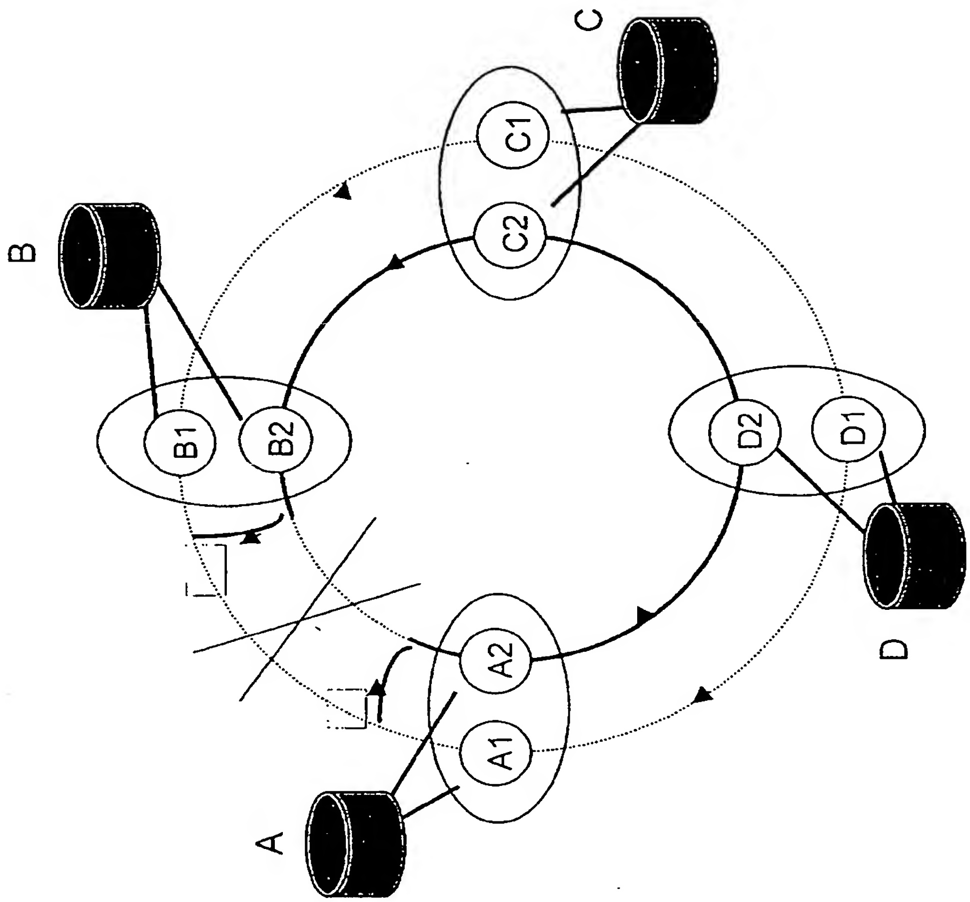


Figure 12

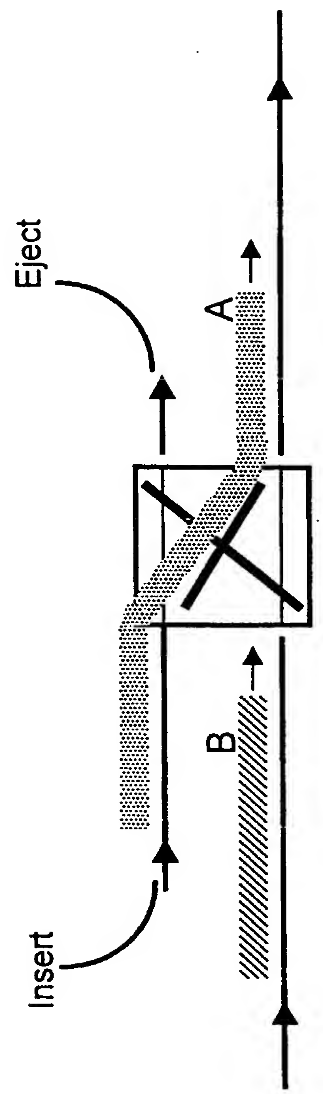


Figure 13

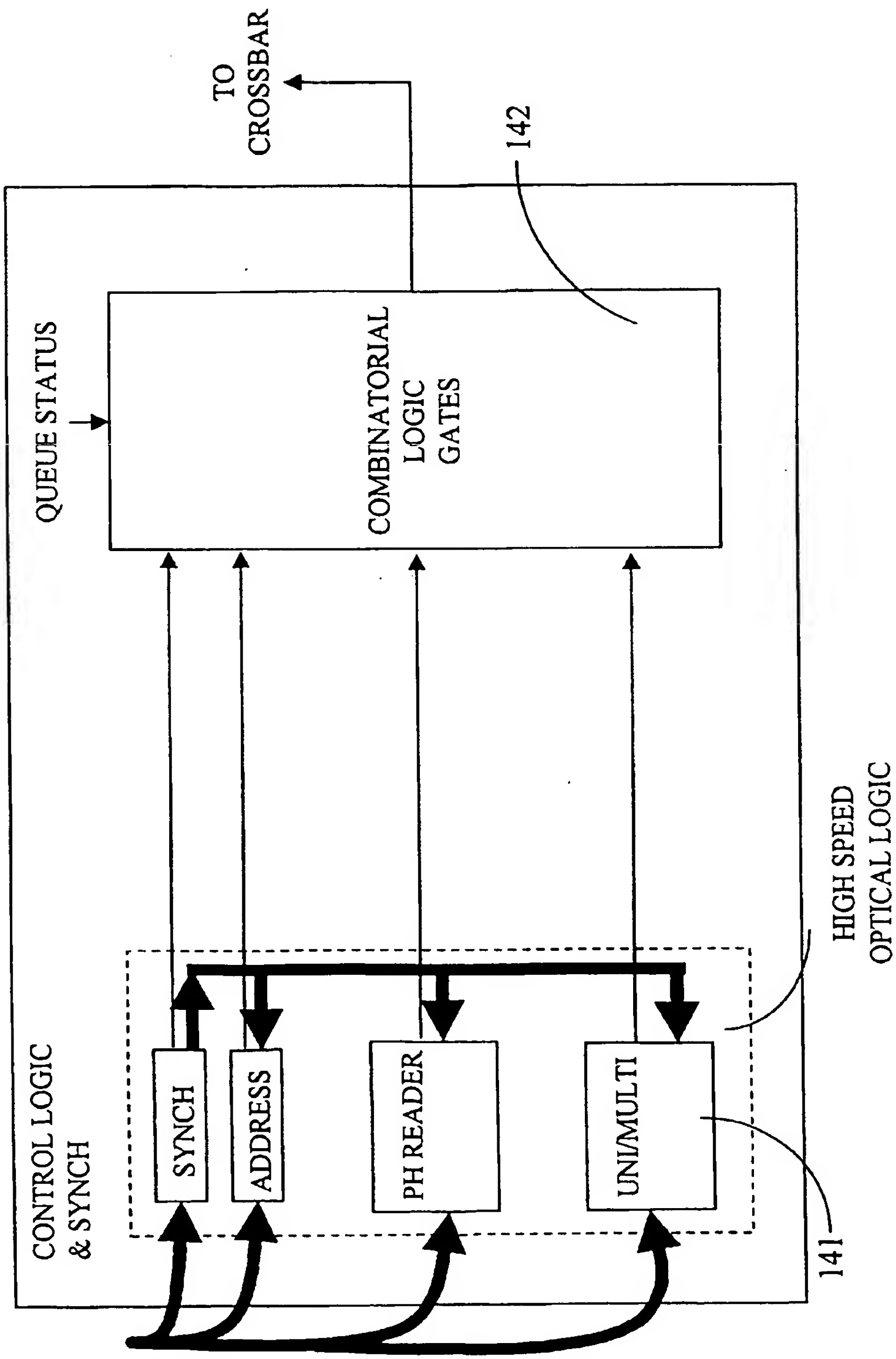

TO
CROSSBAR
142
QUEUE STATUS
COMBINATORIAL
LOGIC
GATES
CONTROL LOGIC
& SYNCH
SYNCH
ADDRESS
PH READER
UNI/MULTI
HIGH SPEED
OPTICAL LOGIC
141

Figure 14

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 99 30 3679

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	EP 0 462 349 A (IBM) 27 December 1991 (1991-12-27) * page 2, line 1 - line 5 * * page 2, line 47 - line 55 * * page 4, line 46 - line 48 * * page 5, line 35 - page 6, line 37 * * page 7, line 2 - line 56 * * figure 4 *	1-11	H04L12/43 H04Q11/00 H04L12/56
D,A	SAUER J R ET AL: "A SOLITON RING NETWORK" JOURNAL OF LIGHTWAVE TECHNOLOGY, vol. 11, no. 12, 1 December 1993 (1993-12-01), pages 2182-2190, XP000422682 ISSN: 0733-8724 * page 2183, paragraph II - page 2184; figures 1-3 *	1-11	
A	EP 0 405 756 A (HOWES NICHOLAS J) 2 January 1991 (1991-01-02) * page 5, line 7 - line 28 * * page 7, line 12 - line 21 * * page 15, line 2 - line 22 * * page 15, line 45 - page 16, line 14 *	12	TECHNICAL FIELDS SEARCHED (Int.Cl.7) H04L H04Q

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	5 January 2000	Meurisse, W

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

European Patent Office

Application Number
EP 99 30 3679

CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing more than ten claims.

☐ Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims and for those claims for which claims fees have been paid, namely claim(s):

☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

☒ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

☐ As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.

☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:

☐ None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

European Patent Office

LACK OF UNITY OF INVENTION
SHEET B

Application Number
EP 99 30 3679

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. Claims: 1-11

   Communications network using priority classes

2. Claim : 12

   Communications system comprising duplicate transmission paths

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 99 30 3679

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report
The members are as contained in the European Patent Office EDP file on
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05-01-2000

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0462349 A	27-12-1991	DE 69017203 D	30-03-1995
		DE 69017203 T	10-08-1995
		JP 2022732 C	26-02-1996
		JP 4233354 A	21-08-1992
		JP 7054939 B	07-06-1995
		US 5140587 A	18-08-1992
EP 0405756 A	02-01-1991	US 5113398 A	12-05-1992

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82